Designing For Biodiversity The Value of Nature Centric Design

Illustrated Methodology 8th July 2024 WOHA, in collaboration with BioSEA, was awarded a Good Design Research grant by the DesignSingapore Council to develop a framework to quantify and communicate the benefits of naturecentric design.

While the significance of landscape integrated architecture to the development of healthy cities, strong communities and rich urban space is well understood, the contribution of these green spaces to the biodiversity, thermal comfort and ecosystems services of our cities has been intuited but proven difficult to quantify.

Taking WOHA's built works as test cases, a comparative methodology was developed to enable a holistic and empirical understanding of the benefits of nature-centric design.

By sharing this analytical framework, WOHA hopes to enable other practitioners to assess and to advocate the success of their own nature-centric designs.



- 1 Nature Centric Design
- **2 Evaluation Framework**
- **3** Towards a Toolkit



Nature Centric Design WOHA









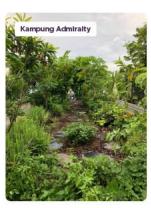
Nature Centric Design Urban Biodiversity



A yellow-back carpenter bee Xylocopa Flavonigrescens



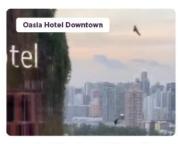
A spotted dove in its nest



Thriving Tropical Plant Species Rooftop Community Garden



A broad-footed carpenter bee Xylocopa Latipes



A pair of Himalayan Griffon vultures



A family of small-clawed otters



An olive-backed sunbird



Asian Glossy Starlings Juveniles and Adult



A family of small-clawed otters



A lemon emigrant butterfly Catopsilia Pomona



A honey bee feeding on an eranthemum Pseuderanthemum Reticulatum

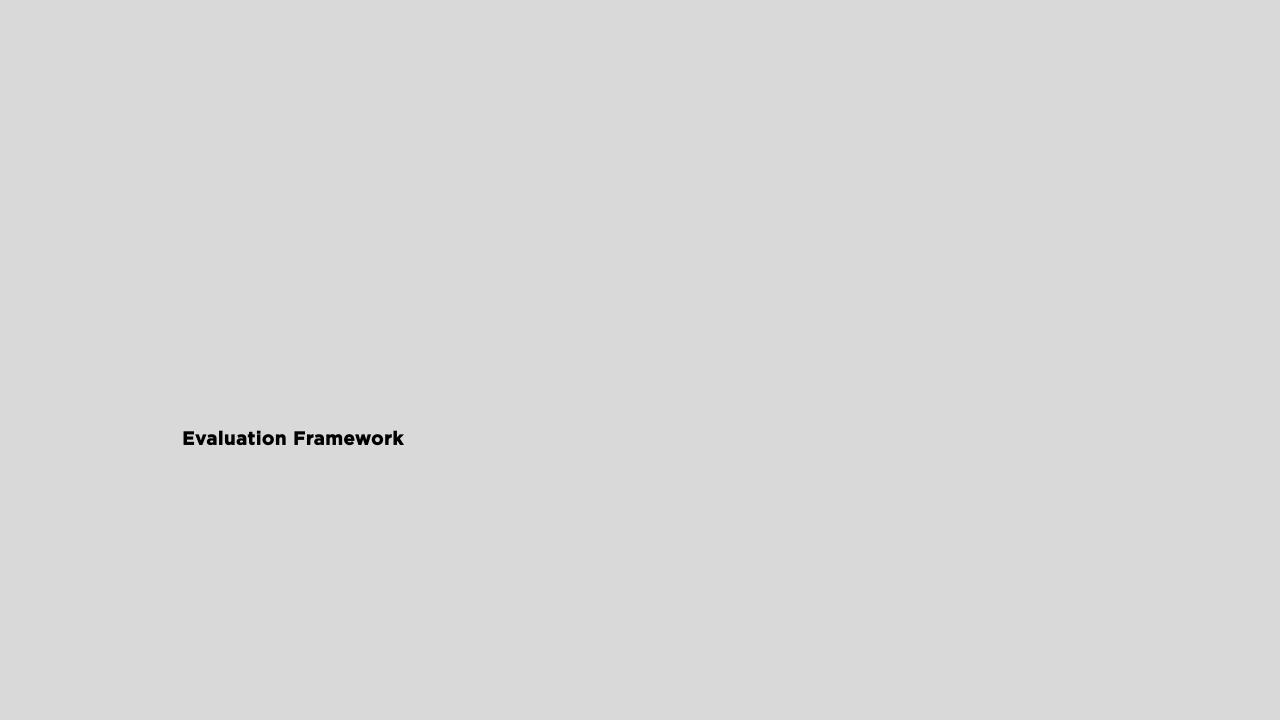


A lesser dog faced fruit bat

Images collected 2018 - 2021

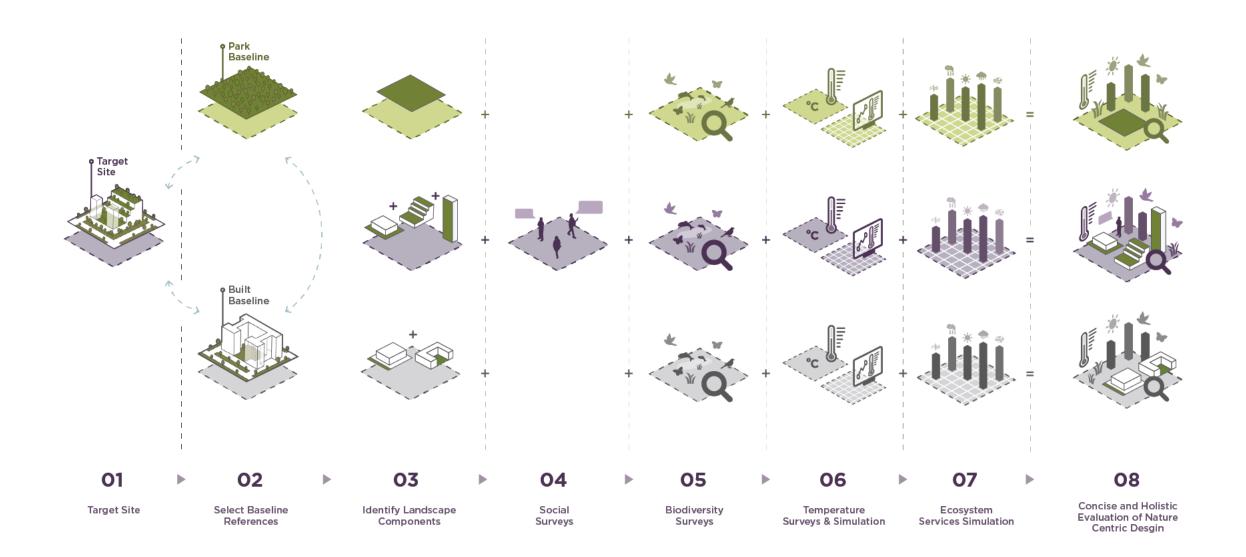






Evaluation Framework

A Holistic Methodology



1 Evaluation Framework Target Sites



Parkroyal Collection Pickering



Skyville@Dawson



Enabling Village



Kampung Admiralty



Oasia Hotel Downtown

1 Evaluation Framework Target Sites



Parkroyal Collection Pickering



Skyville@Dawson



Enabling Village



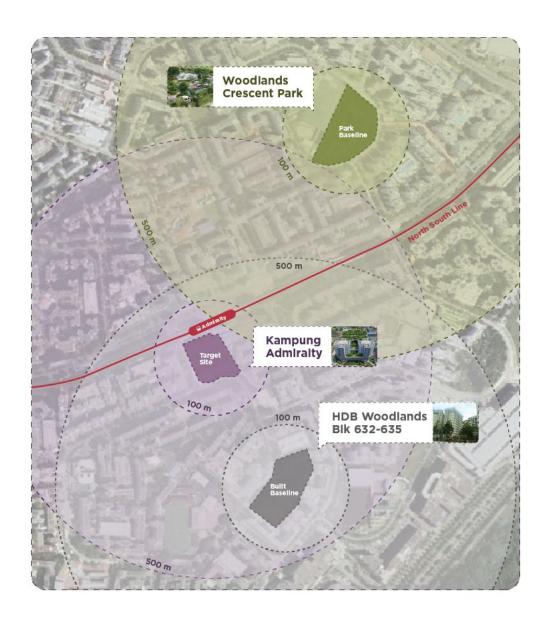
Kampung Admiralty



Oasia Hotel Downtown

Evaluation Framework Select Baseline References

- Biodiversity surveys at target sites can reveal a lot of good information but results remain hard to contextualize. Establishing a built reference and natural reference (such as a nearby forest or park) as two extremes allow contextualization of results to the biodiversity of the neighborhood where the target site is located.
- Reference sites should not be too close to the target site otherwise they may directly interact and influence each other. They should also not be too far from the target site otherwise they are not representative of the neighborhood. An ideal distance range to aim for is 100 -500 m.
- Built Benchmarks should have as close a form and program type as the target site to have comparable results.
- The benchmarks should also be of comparable size. This can be particularly challenging for natural reference sites because their sizes can vary many times across urban contexts. If a larger forest (or park) must be chosen as reference, a patch of comparable size as the target site must be demarcated for surveys.





Evaluation Framework Select Baseline References

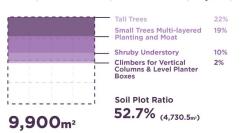
Kampung **Admiralty** **HDB** Woodlands Woodlands **Crescent Park**



Storeys: 11

Program:

Retail, Hawker Centre, Medical Centre, Daycare, HDB

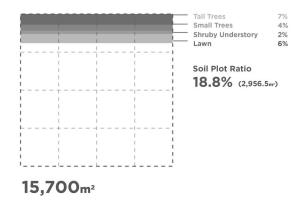




Storeys: 12

Program:

HDB

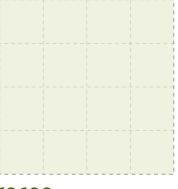




Storeys: NA

Program:

Public Park

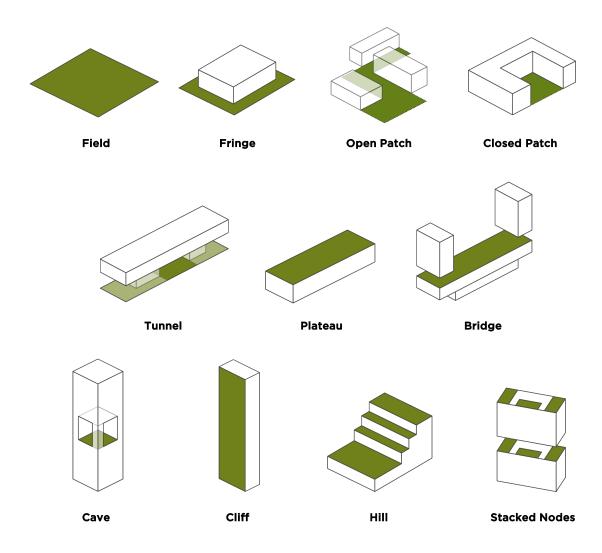


18,100m²



3 Evaluation Framework Identify Landscape Elements

- Defining the subject sites according to the taxonomy of integrated landscape forms enables their relative effectiveness to be assessed.
- "Soil Plot Ratio" is a new metric defined as the total soil area (accumulated across green areas on ground and various levels) divided by the total plot area.
- We recommend classifying greenery and water bodies according to the vegetation complexity of habitat patches such as large trees, small trees, 2-tiered vegetation, multi-tiered vegetation, shrubs, grass, lawn, bioswale, pond etc. These habitats should be ground truthed during site surveys.
- For water habitats, the classification included the known/estimated proportions (length, width and depth) of the water bodies as well as the extent and type of riparian vegetation in them.

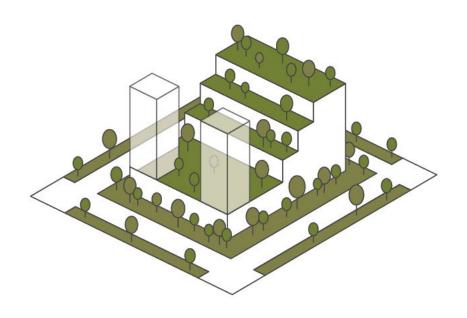


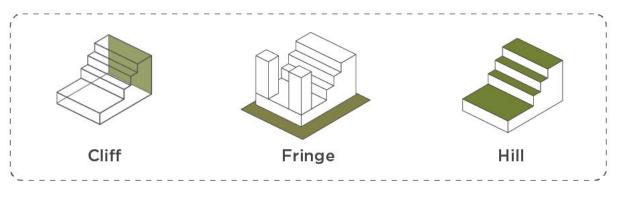


Evaluation FrameworkIdentify Landscape Elements

Cliff + Fringe + Hill

Kampung Admiralty











Cliff

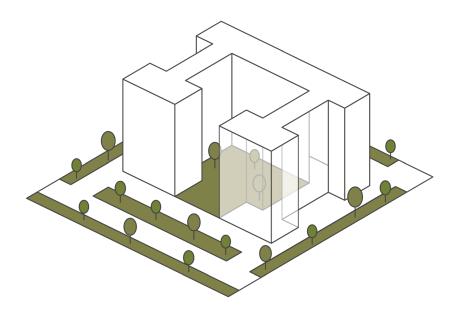
Fringe

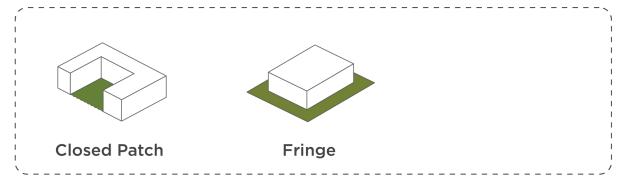
Hill

Evaluation FrameworkIdentify Landscape Elements

Closed Patch + Fringe

Woodlands HDB









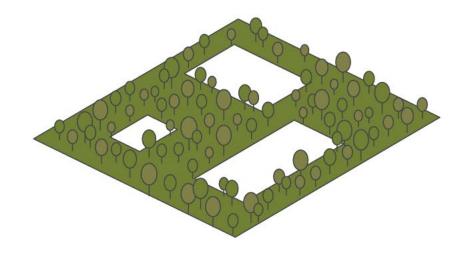
Closed Patch

Fringe

3 Evaluation Framework Identify Landscape Elements

Field

Woodlands Crescent Park

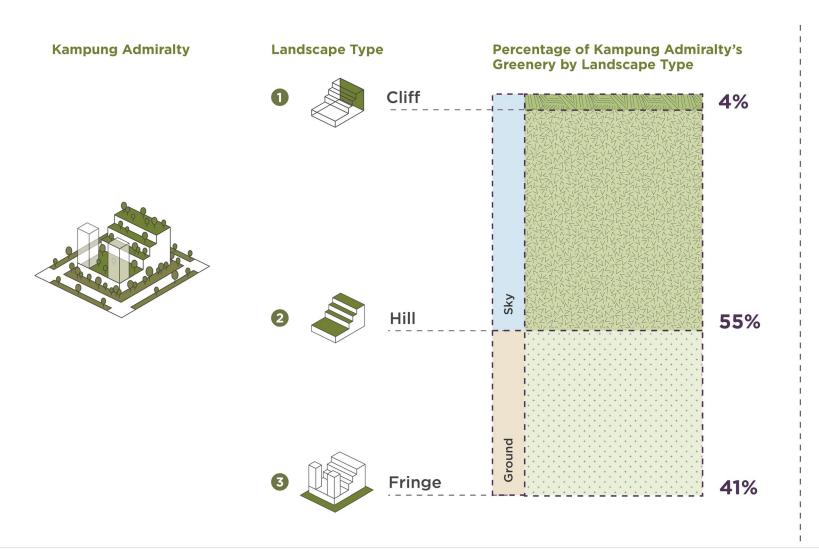




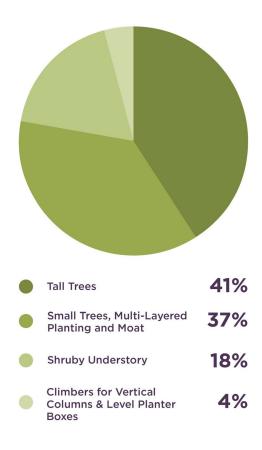


Field

3 Evaluation Framework Identify Landscape Elements

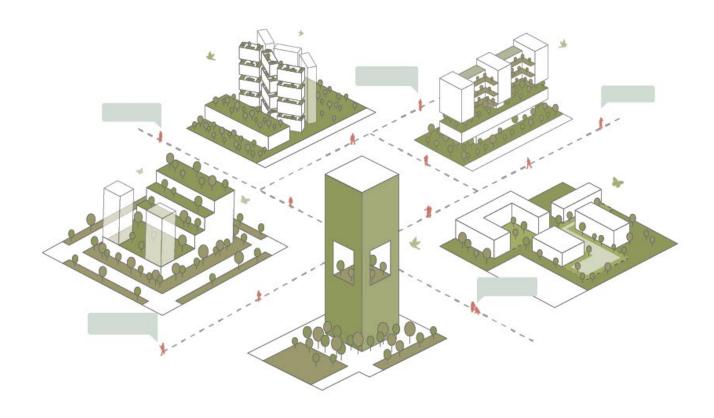


Percentage of Kampung Admiralty's Greenery by Vegetation Type



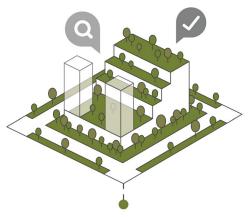
Evaluation Framework Social Survey

- The benefits of green space to wellbeing is well known. More so, it can be fundamental to place making in a building and can play a fundamental role in how people use and perceive a space.
- We suggest semi-structured interviews (preferably in-person) to engage the site's residents / visitors / users about their perceptions towards the value of greenery on site. If in-person interviews are not possible, other broadcast mediums such QR codes placed at signboards or other broadcast channels for the building can be used.
- We recommend at least 30 high-quality interviews of users who know and interact with the target site preferably with varied demographics distributed across age groups, race, gender, and profession.

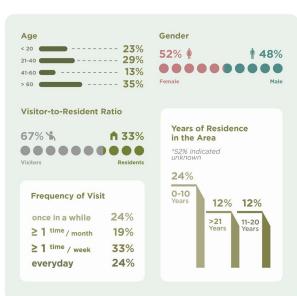




4 Evaluation Framework Social Survey



Respondents



Social Survey Questionnaire

Vis

Reasons to Visit

- 1. What brings you to Kampung Admiralty?
- 2. If visiting, how often do you visit?

H M

Resident Views of Greenery

- 1. If you live here, does your home have a view of green space?
- 2. If yes, how much time do you spend looking at that green space, as compared to other spaces in the area?
- 3. Has the amount of greenery at Kampung Admiralty influenced your choice of living here?



Soundscape

- 1. Does industrial and traffic noise reach your home?
- 2. Do you hear natural sounds from your home (singing birds, flowing water, wind in vegetation)?



Use of Green Spaces

- How long do you usually spend at Kamupung Admiralty's green spaces during every visit?
- 2. Do you spend time in these spaces alone or with others?
- 3. Have you met new people through these spaces?
- 4. What type of activities do you do at these green spaces?
- 5. Which green space at Kampung Admiralty do you spend the most time at?
- 6. How do you think the greenery contributes to the community here?



Species Diversity

- 1. Have you witnessed the following animals at Kampung Admiralty (Small and larger birds, small and medium-sized mammals, insects, fish)?
- 2. What kind of animals are you comfortable to be around?
- 3. Which birds/mammals/insects do you wish to see more or less of?





- Are there any specific elements or features you would like to see added to the green spaces?
- 2. Do you think it is important to include greenery and water when planning for urban spaces?
- 3. Why?
 - A. Naturalise and enliven
 - B. Cooling benefits
 - C. Captures carbon
 - D. Important for biodiversity
 - E. Relaxing, calming
 - F. Exercise
 - G. Purifies
- 4. How often do you visit nature areas in Singapore (or elsewhere)? Why?
- 5. Do you think Kampung Admiralty would see the same level of demand and popularity without its outdoor spaces, viewpoints and greenery?



Evaluation Framework Social Survey

67%

spend time in Kampung Admiralty's green spaces with friends, family or acquaintances

52% © >30 7 in 11

respondents spend more than 30 minutes per visit at the green spaces

42%

of respondents have met new people through the green spaces at Kampung Admiralty

76%

of respondents think it is important to have greenery in urban spaces

residents frequent its green spaces more than 3 times per week

84% Relaxing 54% Cooling

Relaxing and cooling properties were the top reasons why respondents liked these green spaces

- Being 90+ years old, I like living here as it is quiet, clean and convenient. In the past, I bring my friends to the community farm to hang out there.
- My kids enjoy spotting animals in the moat. I like bringing them around the playground and green spaces to explore and play too.



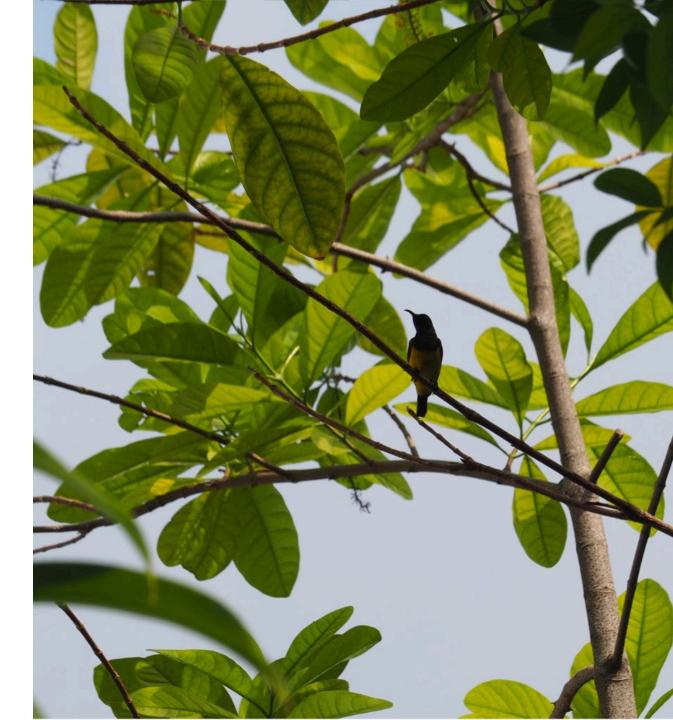




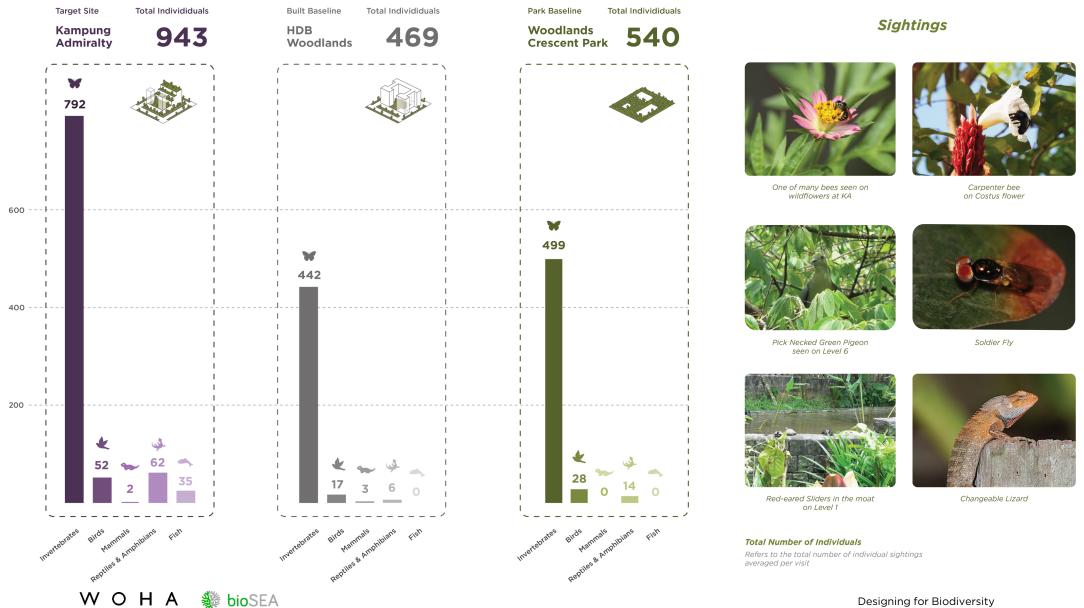


Evaluation Framework Biodiversity Survey

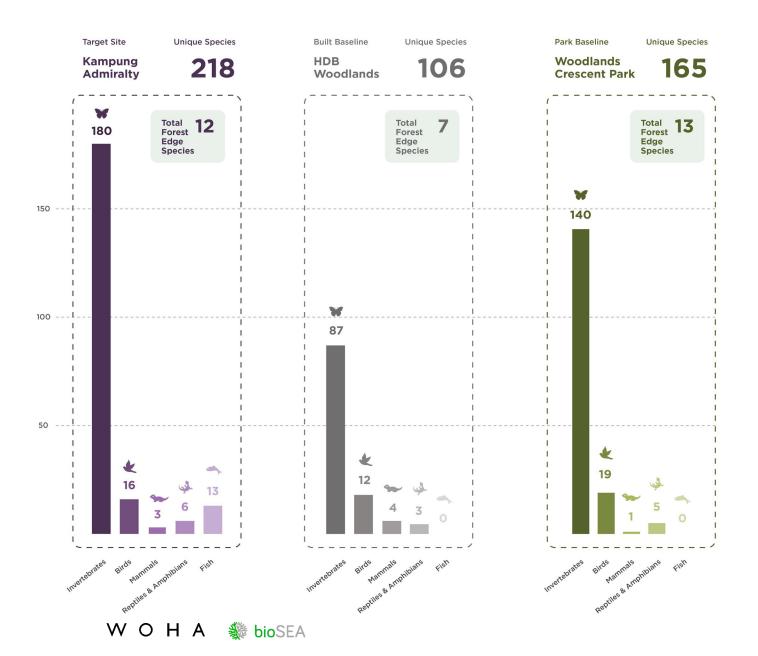
- A minimum of 4 biodiversity surveys are recommended with at least one nocturnal survey per site.
- Consider surveying all key fauna groups covering both flying animals (such as birds, butterflies, dragonflies, beetles and other insects and bats) as well as ground animals (such as reptiles and amphibians), aquatic fauna (such as fish), mammals.
- Insects constitute the bulk of species observed in our surveys. Therefore, a robust insect survey is likely to show biodiversity benefits more holistically.
- Species present can be analyzed by various guilds including nativeness status, red list status, potential pest species, If they could be used as vector control and their habitat preference (such as urban adapted, forest edge or dependent species). These classifications allow inferences towards the value of species observed



Evaluation Framework Biodiversity: Species Intensity



Evaluation Framework Biodiversity: Species Diversity



Species **Enhancement Ratio**

Species Richness Ratio

Kampung Admiralty

376%

vs Built Baseline

Area linear corrected

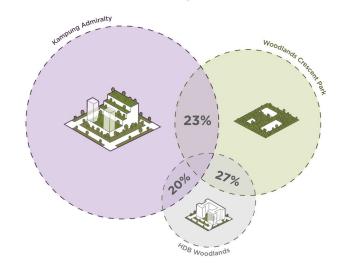
Kampung Admiralty

210%

vs Park Baseline

Area linear corrected

Shared Species



Species Diversity

to individual number of species, not total number of sightings

Forest Edge Species

Species numbers displayed refers Found at the edge of forested areas, they typically live in the forests but also venture out into nearby urban areas to feed.

Evaluation Framework Thermal Comfort

- Building performance teams typically study sunpath diagrams and wind movements to optimize thermal comfort and derive building shape and form. Separately, thermal comfort/cooling offered by building greenery can be studied by modeling the buildings with established CFD softwares such as ENVI-met. These tools need building 3D models with various greenery layers added to them. We defined 30 different tree types for our study with various crown shape and sizes to suit vegetation type and context.
- A simple way to quantify cooling benefits of greenery is to utilise iButton data loggers. These are portable, lightweight and affordable. They can be attached to various substrates (tree trunks, building walls etc.) and programmed to collect data at set intervals (e.g., every 5 minutes). We recommend collecting at 3 days worth of data from an iButton at any location. In our experience, 6 - 8 loggers installed at different locations in the building provide good coverage across building heights and diversity of open spaces.
- A simple hand-held temperature and humidity meter can also be used to capture more sporadic changes. Measurements can be repeated multi-times during the day at multiple locations of the buildings to complement iButton measurements



7 Evaluation Framework Thermal Comfort

Mean Percentile Temperature

Temperature **① Locations of Temperature Loggers** 1.3°C Control Farm Rooftop Mean percentile temperature (°C) Max Reduction in Level 8 Veg Mean Percentile Level 6 Veg Temp Level 4 Veg Moat Veg Ground Veg Control Wall Close-Up of IButton Temperatures were Green Wall recorded every 10 minutes for 3 days continuously, via iButton temperature loggers

Evaluation Framework Thermal Comfort

Air Temperature

Without Vegetation With Vegetation Air Temeperature Average from 33.3 °C to 32.39 °C Ground **↓0.82°**c (1.8m) from 32.98 °C to 31.68 °C Level 6

Rooftop

<31.3 °C >33.7 °C UTCI

Universal Thermal Climate Index

UTCI Average

from 42.98 °C to 35.74 °C **↓ 7.24°**^c

from 45.85 °C to 33.61 °C

from 42.57 °C to 33.91 °C **↓8.66°**°c

UTCI (Universal Thermal Comcfort Index) is a commonly used parameter to evaluate outdoor thermal comfort for humans as it describes the heat exchange between the human body and its thermal environment





from 32.0 °C to 31.39 °C

Evaluation Framework Ecosystem Services Simulation

- Ecosystem services are the various benefits that humans derive from healthy ecosystems. These ecosystems, when functioning well, offer such things as provision of food, natural pollination of crops, clean air and water, decomposition of wastes, or flood control.
- Greenery and water bodies on buildings create ecosystems that contribute to many such benefits as well.
- Many ecosystem service evaluation tools exist but only few work well at building scales and can incorporate verticality of greenery in buildings. We recommend using tools such as ESII, Ecosystem Intelligence and ENVI-met to quantify carbon sequestration, air filtration, solar heat reduction potential of greenery and water systems for the target projects.
- Such calculations require a mapping of the site's greenery by various vegetation types such as tall trees with multi-layered plantings, small trees with 2-tiered plantings, streetscape, shrubs only, lawn, ornamental water body etc., quantification of planting density, height of dominant vegetation, soil types, major slopes/depression points etc.



9 Evaluation Framework Ecosystem Services Simulation



Air Temperature Regulation

The thermal benefits provided by shading, evaporative cooling, surface albedo etc. that affect temperature within a localized area.



Carbon Stored

The amount /
percentage of carbon
sequestered by the
vegetation directly
contributing to combat
climate change. The
value includes aboveground and belowground carbon biomass.
Relationships between
above and belowground biomass were
made using established
allometric equations.



Air Nitrogen Removal

The amount/percentage of airborne nitrogenoxygen compounds sequestered through interaction with vegetation. NOx is an irritant which causes inflammation of airways in humans at high concentrations. Vehicles are the biggest emitters of NOx in cities.



Air Particulate Removal

The amount /
percentage of airborne
particulate matter in the
PM10 range sequestered
through interaction with
vegetation. Fine
particles in air can get
deep into lungs and
some into the
bloodstream causing
lung and heart
problems.



Air Filtration

The ability of landscape and design features to filter and protect people from pollutants emitted or mobilized by wind, vehicles, or other forces. These pollutants include Particulate Matter, Nitrogenoxygen compounds, sulphur oxygen compounds, chlorofluorocarbons and other compounds.

Simulation outputs are presented as percentage performance to a pristine habitat of equivalent site area. If a pristine habitat's performance is 100% (green bars), the purple and grey bars indicate how well does the target site and built reference site compare with in terms of percentage performance of each ecosystem service.



Evaluation Framework Ecosystem Services

Performance Compared to a Pristine Habitat of Equivalent Site Area



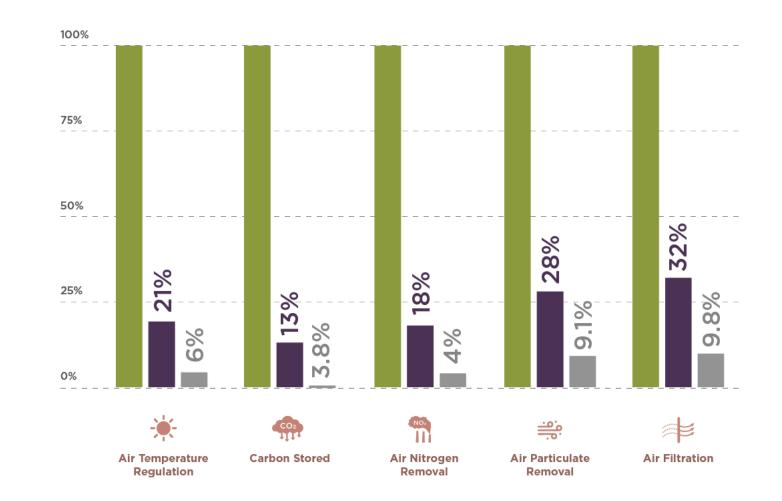
4,730 m² Pristine Habitat



Kampung Admiralty



HDB Woodlands Ring Road



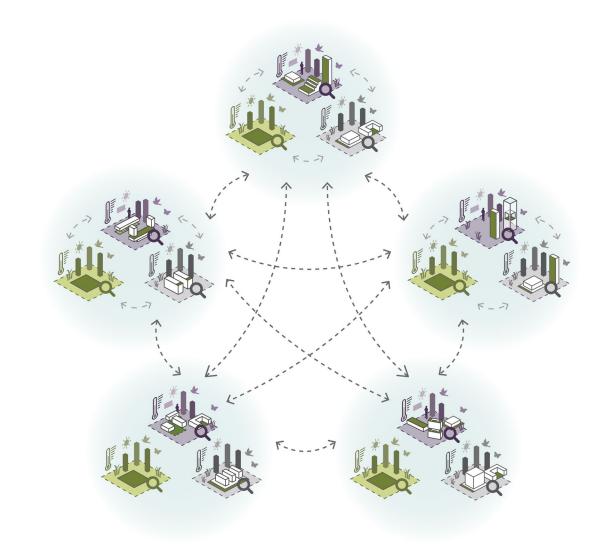






First Steps

- · The multitude of external factors that determines the ecological performance of a site makes direct comparison between two natureoriented projects extremely difficult.
- Creating a framework that's based on the comparative evaluation of a target site and bookended baselines enables the relative performance of these clusters to be compared against one another.
- The five cases here provide a very limited data pool. This exercise is a first step in the development of scoring system for natureoriented design.
- This method could also overcome regional particularities, enabling far reaching comparisons and collaborations.
- By making the framework public domain and by publishing and promoting the performance of WOHA's projects the team hopes to inspire and enable other designers to adopt the methodology and in turn expand the data pool
- With a sufficiently large body of data the scoring systems could become robust enough to release as a toolkit.



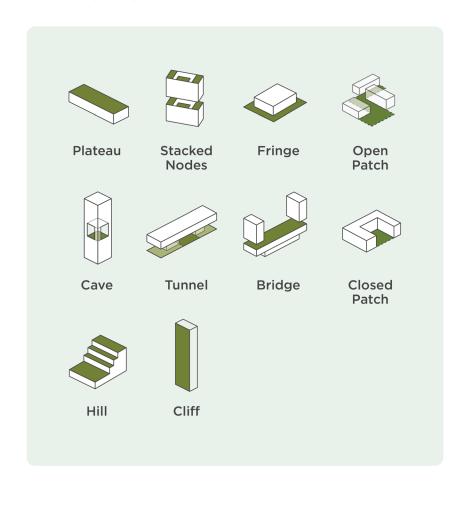


Project Composition

Percentage of Soil Area by Landscape Type



Landscape Types



Project Biodiversity

Target Sites



Kampung Admiralty



Oasia Hotel Downtown



Enabling Village



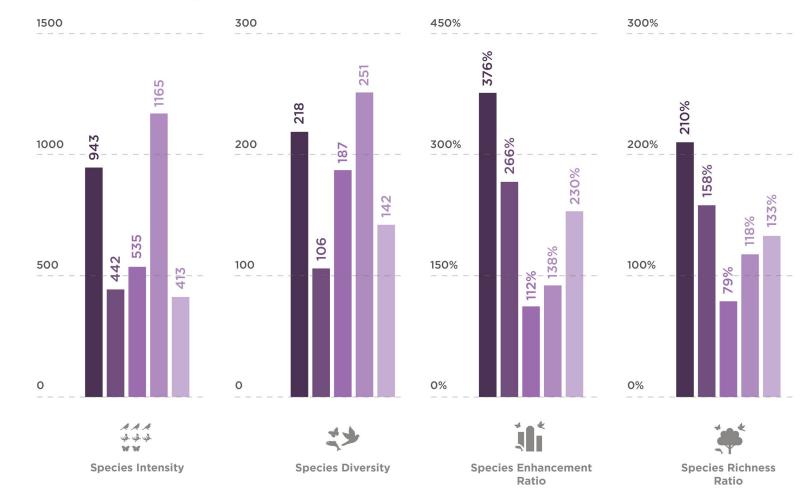
Skyville @ Dawson



Parkroyal Collection Pickering

Rating Biodiversity

Biodiversity Results Across Target Sites





Rating Biodiversity

Building Biodiversity Rating

Ground-to-Total Species Ratio

Rewards good design of ground habitats in a project with vertical greenery. It recognises the fact that ground habitats are highly valuable for ground/crawling animals such as reptiles and amphibians, ground mammals etc.

Sky-to-Ground Species Ratio

A measure of wholeness in green design which rewards good balance of vertical habitats vs ground habitats

Forest Edge to Total Species Ratio

A measure of conservation significance of the design recognising the number of forest edge species that a design can support

Species Enhancement Ratio

Rewards the potential for good greenery design in the context of other buildings / built references in the neighbourhood (within 500m)

Species Richness Ratio

Rewards the potential for good greenery design in the context of natural references in the neihbourhood (within 500m)

Building Biodiversity Rating

> Ground-to-Total **Species Ratio**

Sky-to-Ground **Species Ratio**

Forest Edge to Total Species Ratio

Species Enhancement Ratio

Species Richness Ratio

Formula

Species at Ground Level Total Species on Site

Formula

Species in Vertical Habitats _ x 100% Species at Ground Level

Formula

Forest Edge Species on Site - x 100% Total Species on Site

Formula

Total Species at Target Site (linear corrected per ha)

x 100%

Total Species at Built Baseline (linear corrected per ha)

Formula

Total Species at Target Site (linear corrected per ha) x 100%

Total Species at Park Baseline (linear corrected per ha)

Scoring

Exceptional >80% Very Good 60-80% 40-60% Good Moderate 20-40% <20% Poor

Scoring

Exceptional >200% Very Good 100-200% 50-100% Good Moderate 20-50% Poor <20% Scoring

Exceptional >10% Very Good 9-10% Good 6-9% Moderate 3-6% Poor <3% Scoring

Exceptional >200% Very Good 100-200% 50-100% Good Moderate 20-50% Poor <20% Scoring

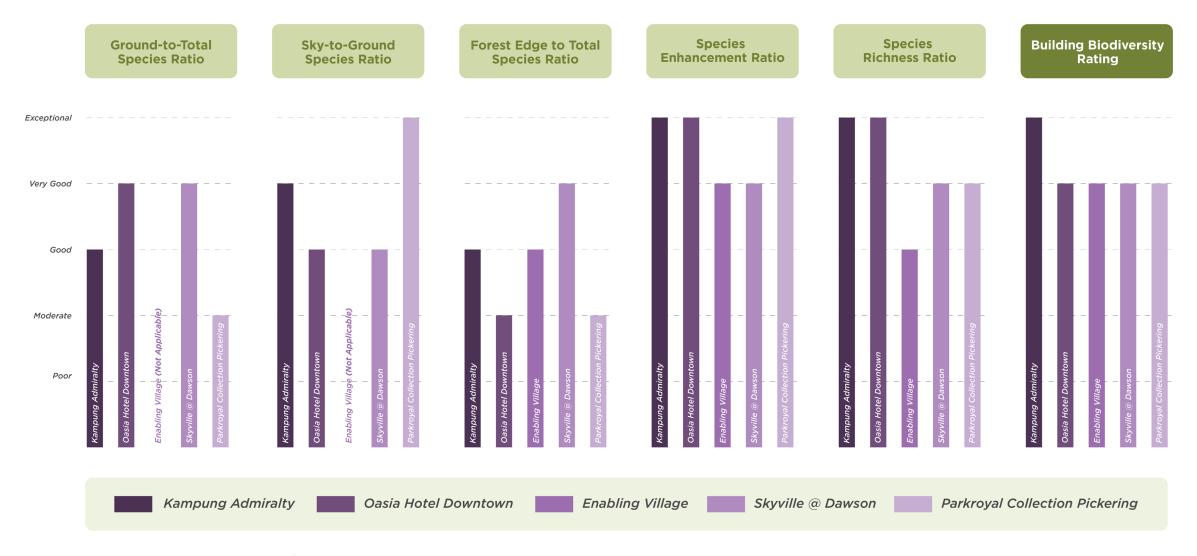
Exceptional >150% Very Good 100-150% Good 30-100% Moderate 10-30% Poor <10% Scoring

Exceptional >80% Very Good 60-80% Good 40-60% Moderate 20-40% Poor <20%



Rating Biodiversity

Building Biodiversity Rating



Project Ecosystem Services

Target Sites



Kampung Admiralty



Oasia Hotel Downtown



Enabling Village



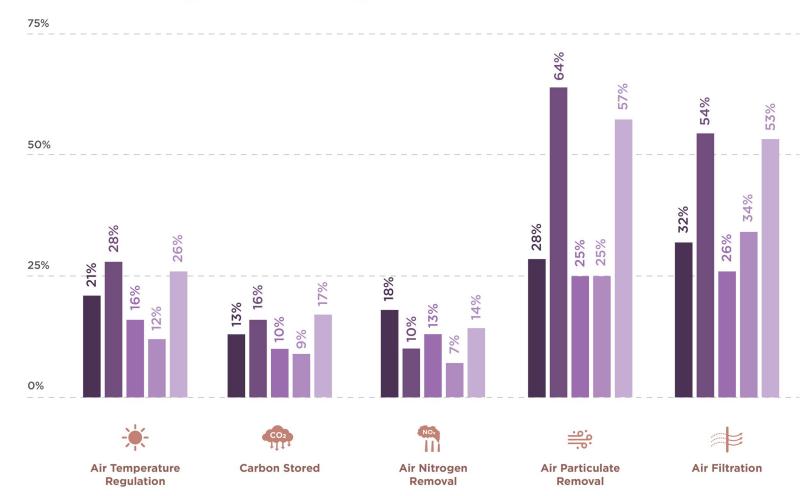
Skyville @ Dawson



Parkroyal Collection Pickering

Ecosystem Services: Simulated Results

Performance of Each Site compared to a Pristine Habitat of Equivalent Site Area



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